# SYNOPSIS

**'Antimicrobial Study of doped M-type Barium hexa ferrites against Pathogens'**


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## 1. INTRODUCTION

Investigating the antimicrobial properties of various substances is essential in addressing the escalating challenge of resistance to antibiotics and antifungal agents. Research in this field has elucidated a diverse array of compounds with potential antimicrobial applications, including synthetically derived substances, plant extracts, and nanoparticles(Shahbazi, 2019). Nanoparticles have been acknowledged for their considerable antifungal properties, which are vital for enhancing agricultural productivity and managing plant diseases, especially plant pathogens(Nizamani et al., 2024). The utilization of nanoparticles exhibits promising outcomes in two key areas: plant disease management and the food packaging industry. The primary objective of this application is to enhance quality and simultaneously mitigate the negative consequences of microbial contamination, particularly those resulting from bacterial and fungal infections(Karimi, 2019). Maize, often referred to as the "wonder crop," has the potential to revolutionize the agricultural industry due to its high yield. It also has the potential to significantly contribute to food and nutritional security in India and globally. However, it is vulnerable to the destructive disease, banded leaf and sheath blight, caused by the pathogen R. solani, which can attack a wide range of host plants, including maize and cause seed decay. Despite its potential, maize faces challenges such as disease susceptibility(Singh et al., 2019). Colletotrichum truncatum, the prevalent pathogenic fungus responsible for anthracnose, is a highly destructive species that affects a wide range of host crops, such as soybean(Gawade et al., 2009). Nevertheless, in terms of environmental and human health considerations, there are certain challenges associated with controlling this pathogen using chemical fungicides, which are commonly used in contemporary agriculture (Meng et al., 2010). Owing to the increasing demand for environmentally friendly methods for material synthesis, the synthesis of nanoparticles has garnered attention as a promising area of research at the intersection of nanotechnology and biotechnology. Nanoparticles, which possess a high surface-area-to-volume ratio and exhibit potent antimicrobial properties, are considered the most promising candidates for this endeavor (Fayaz et al., 2010). Ferrite is a category of magnetic oxide compounds that primarily comprise iron oxide as a principal component. The most well-known ferrite is magnetite ($Fe_3O_4$), also known as loadstone, which was the first magnetic material to be identified by ancient civilizations. Ferrites are a distinct class of composite compounds that contain lanthanides and robust transition metals including iron, chromium, and manganese.(Srivastava and Yadav, 2012). Permanent magnets, also known as hard

magnetic materials, possess high coercivity, which enables them to generate substantial forces without requiring a current-carrying coil. The ability of a material to maintain strong net magnetization and stability in the presence of external fields is a defining characteristic of a permanent magnet. The high coercivity of a permanent magnet is crucial in determining its efficacy(Hirosawa et al., 1990). BaFe12O19, commonly referred to as BaM, a magnetic material of considerable scientific and technological significance, is prized for its high Curie temperature, strong coercive force, substantial magnetic anisotropy field, exceptional chemical stability, and resistance to corrosion. Its increasing use in magnetic storage devices has led to growing interest in methods for processing fine barium hexaferrite particles in recent years. The synthesis process has a significant impact on the characteristics of powder particles, including their homogeneity, composition, and magnetic properties(Hirosawa et al., 1990). Recently, the utilization of hexagonal ferrites has attracted considerable interest from diverse industries, particularly in the development of permanent magnets and electronic devices. These magnetic compounds exhibit remarkable characteristics and have promising applications in a wide range of fields.(Kojima, 1982). M-ferrite, a type of hexagonal ferrite, is composed of S and R blocks. The barium atom occupies a plane referred to as the mirror plane, where the S and R blocks undergo 180-degree rotation around the c-axis. This results in the mirror block R, R* giving the unit cell formula SRS*R*, BaM ferrite has been extensively researched, particularly with regards to its 180-degree rotation around the c-axis, which is composed of stacked spinel-like blocks and substituted M-type ferrite, as observed in the case of $BaFe_{12-X}A_XO_{19}$(Albanese and Deriu, 1979). Using the citrate precursor technique, which is commonly referred to as the Pecchini method, substantial quantities of ferrite powder can be produced with outstanding results(Ahmed et al., 2004). Moreover, it is employed in the low-temperature range to generate ultrafine particles from the disintegrated citrates(Kimura et al., Sankaranarayanan et al., 1993). Several modifications have been made to ferrite in order to enhance its purity, specifically to raise the saturation magnetization value. Amongst the M-type hexaferrites, BaM, consisting of barium, holds the greatest significance(Brahma et al., 1992). There is a tremendous incentive to create new bactericides because there is a serious public health issue with the emergence of new bacterial strains that are resistant to existing antibiotics (Guzman et al., 2012).

## 2. LITERATURE REVIEW

**V.K. Sankaranarayanan et. al (1996)** has been demonstrated that the citrate precursor method enabled the synthesis of nanoscale particles at relatively low temperatures. They synthesized Barrium hexaferrite nanoparticles using the citrate precursor method at different temperatures. According to TEM observations, the average particle sizes for the samples heated to 425, 600, and 700°C are 10-15, 20 nm, and 50 nm, respectively(Sankaranarayanan and Khan, 1996).

**Dimri et al. (2004)** have found that barium hexaferrite nanoparticles, which exhibit electrical and magnetic properties, can be synthesized using the citrate precursor method. This study examines the effects of particle size and capping agent on the final structural, dielectric, and magnetic properties of barium hexaferrite particles.(Dimri et al., 2004).

**Mallick et al. (2007)** reported significant insights by successfully synthesizing a highly stoichiometric and phase-pure barium hexaferrite using a co-precipitation and solid-state preparative method. The method adopted high-purity nitrates, oxides, and carbonates of iron(III), barium(II), and ammonium hydroxide. The results showed that the apparent density increased consistently after each firing cycle. X-ray diffraction studies confirmed the presence of a single phase belonging to the theoretical space group P63/mmc with cell parameters a = b = 5.895Å and c = 23.199Å. Additionally, the DTA results revealed that the hexaferrite formation temperature was 10500C(Mallick et al., 2007).

**Mosleh et al. (2014)** reported that barium hexaferrite nanoparticles were synthesized via a co-precipitation route in the presence of a high concentration of hydroxide ions at low temperatures. In addition, the low-temperature (900C and 5000C) annealed samples were superparamagnetic at room temperature because of their near-zero coercivity and remanence(Mosleh et al., 2014).

**Kaynar et al. (2015)** reported that the single-phase nanocrystalline BaFe12O19 powders with a mean crystallite size of about 50 nm were created using wet milling and heat treatment. However, the structure also contained a few amorphous patches. Additionally, it was found from the magnetic measurements that as the dry milling time increased, saturation magnetization fell from 61 emu/g to 10 emu/g(Kaynar et al., 2015).

**Ishaq, K., et al (2017)** They examined Nickel ferrite Nanopowder's antibacterial efficacy against the three chosen microorganisms, Escherichia coli, Pseudomonas aeruginosa, and Staphylococcus aureus. The nickel ferrite doped alumina's antibacterial activity was tested using the agar well diffusion method(Ishaq et al., 2017).

**Anjum, S., et al.,(2017)** they used Powder metallurgy to create the series of M-type Ba1-xSrxFe12O19 (x=0.0, 0.2, 0.4, 0.6, 0.8, 1) materials. The synthesis of hexa-ferrite was validated by FTIR analysis, which showed that bands in the range 430-590cm-1 are caused by the stretching vibration of oxygen atoms and metal ions (M-O), specifically Fe-O. FSEM is used to calculate the average grain size, which ranges from 0.37 to 1.5 mm(Anjum et al., 2017).

**Chen et al. (2019)** BaYxFe12-xO19 (x ranging from 0.1 to 0.8 with steps of 0.1) hexaferrite, synthesized through ceramic process, showed a decrease in saturation magnetization (Ms) to a minimum of 55.63 emu/g. This was followed by a gradual increase due to the presence of a second phase (Y3Fe5O12). The optimal values of Ms (56.57 emu/g) and Hc (1794.17 Oe) were obtained at x = 0.6, making the material suitable for magnetic recording applications(Chen et al., 2019).

**Lagashetty, et al.(2019)** have learned the nanocomposite has antibacterial activity against a variety of microorganisms. Magnesium ferrite that has been doped with ag has a little antibacterial effect(Lagashetty et al., 2019).

**Bocate, K.P., et al.(2019)** The antifungal activity of biogenic silver nanoparticles (AgNPs) and simvastatin (SIM) was evaluated alone and in combination against three toxigenic species of Aspergillus and two species of Circumdati. The MIC50 of SIM was 19.5 g/mL for the Circumdati species and 78 g/mL for the Flavi species, while AgNPs had an MIC50 of 8 g/mL for the Flavi species and 4 g/mL for the Circumdati species(Bocate et al., 2019).

**Alvino, L., et al. (2020)** reported that the in- vitro and in vivo toxicity of BaFeNPs was evaluated for the first time in model organisms such as bacteria, yeast, and nematodes. Gram-negative (E. coli) and gram-positive (S. aureus) bacteria as well as yeast (C. albicans) were treated with BaFeNPs for the in vitro evaluation, and their growth was unaffected. It would be fascinating to investigate if BaFeNPs would not impact the crucial microbial balance in both the environment and the microbiota of higher animals, including humans, given that they do not appear to effect microbial development(Alvino et al., 2020).

## 3. RESEARCH GAP IDENTIFICTION

The relevance of this research lies in exploring yttrium-doped barium hexa ferrite nanoparticles as potent antimicrobial agents against pathogens that pose significant threats to agricultural crops and plants. With the increasing prevalence of antibiotic-resistant bacterial strains, there is an urgent need for novel bactericides. A comprehensive literature review indicates a lack of studies investigating the antimicrobial effects of yttrium-doped barium hexa ferrites on two prevalent human pathogens (*Escherichia coli and Staphylococcus aureus)* and plant pathogens *(Rhizochotonia saloni and Colletotrichum trunchatum)* using the agar well

diffusion method. Therefore, this investigation aims to synthesize Y-doped barium hexa ferrites through the citrate precursor technique and evaluate their antimicrobial capabilities.

## 4. OBJECTIVES OF THE PRESENT WORK

The primary objectives of this study were as follows:

(i) Fabricating a series of $Y^{3+}$-doped Barium hexa ferrite samples using the Citrate precursor method, with varying compositions of $BaFe_{12-x}Y_xO_{19}$ (x = 0.0, 0.1, 0.2).

(ii) Investigating the structural and optical properties of $Y^{+3}$-doped Barium hexa ferrite samples.

(iii) Assessment of the antibacterial activity of the $Y^{+3}$-doped barium hexa ferrite samples against two common human pathogens, *E. coli and S. aureus*.

*(iv)* Evaluation of the antifungal activity of $Y^{+3}$-doped barium hexa ferrite samples against two plant pathogens: *C. truncatum and R. solani.*

## 5. PROPOSED OUTCOMES OF THE PRESENT WORK

(i) The present investigation aims to demonstrate that the citrate precursor method, a cost-effective approach, can be utilized to synthesize nanoscale hard ferrites.

(ii) The study will include the structural, optical, and morphological examination of the synthesized doped barium hexaferrite nanoparticles.

(iii) This research will focus on the antibacterial effects of nanoferrites against two common human pathogens, namely *Escherichia coli* and *Staphylococcus aureus*.

(iv) This study will also examine the antifungal properties of nanoferrites against two plant pathogens, *Colletotrichum truncatum* and *Rhizoctonia solani*.

## 6. PROPOSED METHODOLOGY

**(i) Synthesis of Yttrium substituted Barium hexa ferrites:** The synthesis of M-type $BaFe_{12-x}Y_xO_{19}$ (x = 0.0, 0.1, 0.2) nanoparticles will be accomplished via the citrate precursor method, using a stoichiometric amount of barium nitrate ($Ba(NO_3)_2$), iron (III) nitrate nonahydrate ($Fe(NO_3)_3.9H_2O$), Yttrium Nitrate ($Y(NO_3)_2$), citric acid ($C_6H_8O_7$), and ammonia solution (25% NH3). A minimum amount of deionized water was used, and iron nitrate was added and heated under constant stirring. Citric acid will be combined with barium nitrate and dissolved in deionized water, with the addition of ammonia for pH adjustment to 7. The mixture will be heated at 800°C, and the solvent will be evaporated. The obtained powder was sintered at 850°C. The phase

compositions of the samples will be analyzed using a CuK X-ray diffractometer, and the bulk densities of the samples will be determined using the Archimedes method.

**(ii) Structural Analysis:** The structural characteristics of the synthesized samples will be examined through X-ray diffraction analysis, which employs Cu-Kα radiation with a wavelength of 1.54 Å.

**(iii) Spectroscopic and IR Studies:** The UV spectroscopic study will be conducted to determine the band gap, while an FTIR study will be conducted to investigate the effect of substitution.

**(iv) Antibacterial Study:** The Y-doped BaFe12O19's antibacterial activity will be assessed using an agar-well diffusion assay. Staphylococcus aureus (MTCC 734) and Escherichia coli (MTCC 739), which are gram-positive and gram-negative bacteria, respectively, will be used to evaluate the antibacterial effects of barium ferrite nanoparticles. The barium ferrite solution will be streaked onto the surface of Mueller-Hinton agar (MHA) dishes using sterilized cotton swabs, and different concentrations of the solution will be placed in the wells at ratios of 1:4, 1:2, 3:4, and 1:1 (25%, 50%, 75%, and 100%, respectively). The positive control will be ciprofloxacin at a concentration of 100 μg/mL. The plates will be incubated at 37°C for 24 h and the inhibitory zones will be measured and recorded after incubation.

**(v) Antifungal Activity:** The antifungal activities of the synthesized samples will be carried out using the agar well diffusion method. To prepare the medium, a combination of the starch-iodate ratio of Potato Dextrose Agar will be mixed with 250 mL sterile water in a flask. The solution will then be sterilized in an autoclave for 20 min. The antifungal activity of the synthesized nanoferrites will be examined against two fungal cultures: Colletotrichum truncatum and Rhizoctonia solani.

## 7. MEASUREMENTS COMPLETED OR OBJECTIVES ACHIEVED

**(i) Synthesis of yttrium-substituted barium hexa nanoferrites:** A series of M-type Ba hexa ferrites doped with Y were prepared using the citrate precursor method.

**(ii) Structural and Morphological study:** X-ray diffraction analysis of the Y-doped series was conducted, and the structural parameters, including particle size and lattice parameter, were determined. Furthermore, the surface morphologies of Y-substituted Ba nanoferrites were investigated using scanning electron microscopy and transmission electron microscopy.

**(iii) UV spectroscopic and FTIR studies:** FTIR and band gap calculations were carried out for the Y-doped series.

**(iv) Antimicrobial study:** The influence of doped barium hexaferrite nanoparticles on plant and human pathogens was evaluated by determining their zone of inhibition.

## 8. THESIS OUTLINE:

**Chapter 1 (Introduction):** This chapter introduces the topic of hard ferrites, discusses their properties, reviews relevant literature, and explains the reasoning behind the doping of yttrium into barium hexaferrites.

**Chapter 2(Experimental and Characterization Techniques):** This chapter delineates the specifics of the materials utilized along with the techniques employed for their synthesis and characterization.

**Chapter 3(Structural, Optical and Morphological study):** This chapter will present the outcomes of the structural, optical, and morphological parameters obtained, along with an explanation of the results obtained.

**Chapter 4(Antimicrobial Study):** This chapter will present the outcomes of antibacterial and antifungal assays, along with an interpretation of the obtained results.

**Chapter 5 (Summary and Conclusion)**: This chapter will Comprises summary of entire study according to objectives along with conclusions. The scope of further research on the basis of recommendations shall also be included in this chapter.

## 9. RESEARCH PLAN SCHEDULE:

| **Research Activity** | **Progress in Months** | | | | | | | | | | | |
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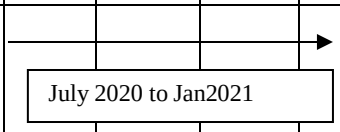
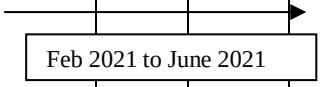
| | **3** | **6** | **9** | **12** | **15** | **18** | **21** | **24** | **27** | **30** | **33** | **36** |
| Course work, extensive literature survey or design of work |   | | | | | | | | | | | |
| Preparation and characterization of the samples | | |   | | | | | | | | | |

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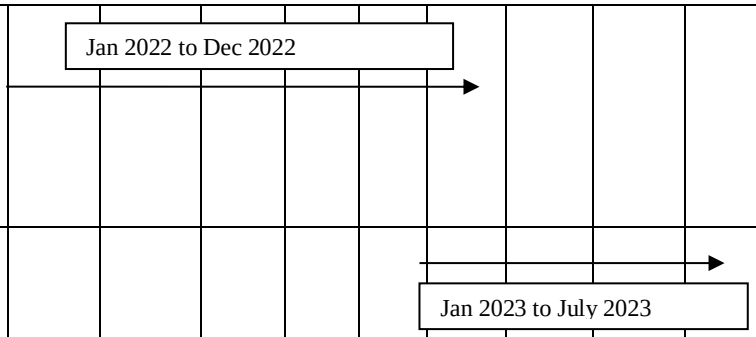
| Manuscripts preparation for publications | | | | | | | | | | | | |
| Thesis writing and thesis submission | | | | | | | | | | | | |



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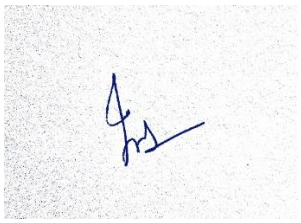

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